THE INVERSION "BRIGHT BAND"

A Feature of Three Winter Storms

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ABSTRACT

Previous discussions of the "bright band," a radar phenomenon associated with the freezing level, have treated it as related to a "normal" lapse rate—a progressive decrease of temperature with height, with surface temperatures above freezing. This paper deals with bright bands observed when surface temperatures were at, or below, freezing. Three cases are examined, all snowstorms of the 1960–61 season. In each case inspection of the available upper-air soundings confirmed the existence of prominent inversions aloft associated with the observed bright bands.

1. INTRODUCTION

The "bright band," a radar phenomenon, is a narrow horizontal zone of relatively high intensity associated with the freezing level and is generally observed in fairly stable precipitation. It is the result of reflectivity changes caused by the melting, coalescence, acceleration of fall velocity, and particle shape differences encountered when snow falls through the freezing level and gradually changes to liquid precipitation. Detailed treatments of the subject have been given by Austin and Bemis [1] and Wexler [2].

The bright band is usually associated with a progressive decrease of temperature with height. This paper discusses it as observed with an inversion aloft, when freezing, or below freezing, temperatures were observed at the station. Three cases are examined, the snowstorms of December 11–12 and December 21, 1960, and that of February 7–8, 1961. In each case the precipitation observed was snow, sleet, or freezing rain.

The observations were made at Washington National Airport, using the Range-Height Indicator (RHI scope) of the WSR–57 Weather Surveillance Radar. In addition, during the storm of February 7–8, 1961, the AN/TPQ–11, a vertically-pointing, cloud-detection radar was available. This radar scans precipitation passing directly overhead. Its presentation is a continuous time-height facsimile recording.

2. OBSERVATIONS

WSR–57 Observations.—Table 1 lists the WSR–57 bright band observations made during the three storms. It also shows some of the surface elements observed at Washington National Airport for corresponding times. Note that in all but two instances, 2100 EST February 7 and 2200 EST February 8 (before precipitation began and after it ended) the surface temperatures were at or below freezing, and the observed precipitation was snow, sleet, freezing rain, or a combination of two or more of these. In each case there was snow on the ground prior to the arrival of the storm.

Considering those observations where both tops and bases were recorded, the thickness of the bright band, with few exceptions, was 2,000 feet. This consistency suggests a beamwidth effect, since it approximates the radar beam's diameter at 10 nautical miles, a critical range in the observations. The small scale of the RHI presentation, and the natural tendency to round observed values off to the nearest thousand feet may also be contributing factors.

Figures 1 and 2 are RHI photographs of bright bands observed during the two December storms. (To define the bright band and remove most of the general precipitation in which it is embedded, reduced gain is employed.) Note the lower, weaker layer in figure 1, almost suggesting a secondary bright band. Although, unfortunately, no upper-air sounding was available at this time (2225 EST), the bright band (6,000 to 8,000 feet) correlates well with the lapse rate at 1800 EST (layer (a) of fig. 3) allowing for a warming trend through the isothermal layer (no bright band was observed at the time of the sounding).

Unless there was a complete reversal of the lapse rate by 2225 EST it seems apparent that the lower, weaker layer (b) of enhanced reflectivity was associated with a freezing, rather than a melting process. The bright band (layer a) first observed at this time suggests an overall warming after the 1800 EST sounding, and implies the presence of some liquid precipitation between the two layers. Assuming that the layer from approximately 2,000 to 4,000 feet remained below freezing, the liquid precipitation falling into this region of ice crystals could have produced (by coalescence) water-coated ice spheres of a diameter greater than that of the raindrops above, the increase in size resulting in a higher radar reflectivity. The base of the layer, at about 2,000 feet, approximates the coldest point of the sounding, and would represent the

TABLE 1.—*Radar and surface observations during three snowstorms at Washington, D.C., when bright band was observed with surface temperature at or below freezing*

Date	Time (EST)	WSR-57 bright band observations			DCA surface observations		
		Observed top base (10^2 ft.)		Remarks	Temperature (° F.)	Ceiling (10^2 ft.)	Weather
12/11/60	2225	80	60	Boundaries approximate	27	10	E-
		40	20				
	2300	80	60		26	6	S-E-
12/12/60	0000	60	40	Visible to south	26	7	S-E-
12/21/60	0200	60	40	Visible 15–20 n. mi. all quadrants	31	21	ZR-S—
	0300	60	40	10–15 n. mi. all quadrants. Base lowering	31	11	ZR-
	0400	60	40	Extends 10 n. mi. north of station	31	7	ZR-
	0500	60	40	10 n. mi. northern quadrants	31	4	ZR-F
	0600	50	30	10 n. mi. northwest of station	32	16	ZR-F
2/7/61	2100	70	x	25 n. mi. to south and southwest. Strongest to south. Precipitation not over station	33	*120	Overcast
2/8/61	0300	60	40	10–15 n. mi. all quadrants	31	15	S—E-ZR—F
	0500	50	30	15 n. mi. most directions	30	14	E—S—F
	0600	50	30	15 n. mi. all quadrants	30	10	S-E--F
	0700	50	30	10–15 n. mi. to south	30	13	S—E—F
	0800	50	30	North of station			
		60	40	South of station	31	13	ZR-E—F
	0900	60	30	Northeast quadrant	31	17	ZR-E-F
	1700	40	x	5–10 n. mi. to east. Ill defined	30	15	E-S—F
	1800	55	x	10 n. mi. to east, 25 to southeast	31	36	ZR-E-
	1900	50	x		31	18	S-E-
	2000	50	x	All quadrants 10 n. mi. Top 45 northwest through southwest	31	26	S-
	2100	50	x	All quadrants 10–15 n. mi. except northwest through southwest	32	29	ZR-S
	2200	50	x	All quadrants to 10 n. mi. Top 45 west of line due south of station	33	*55	Overcast

*At 2100 EST Feb. 7 and 2200 EST Feb. 8, the observed bright bands are below the ceiling heights. This is due to the radar's detection of precipitation aloft (containing bright band) below the ceiling.

completion of the freezing process and the formation of the sleet observed at the airport at this time.

The lower layer was short-lived, and was not reported at the 2300 EST observation. Significantly, the precipitation had changed to snow and sleet, indicating a less efficient melting process and the introduction of both snow and liquid precipitation into the lower layers. This would have resulted in a lower concentration of water-coated spheres, hence a loss of reflectivity, since the radar return from water-coated surfaces is considerably greater than that from snow.

Figures 4, 5, and 6 show bright bands observed during the second December storm and the February storm, superimposed upon upper-air soundings released at the approximate times of the radar observations. All of the soundings feature inversions aloft, generally beginning 1,000 to 2,000 feet above the surface.

In figure 4 the inversion temperature exceeds 0° C., with

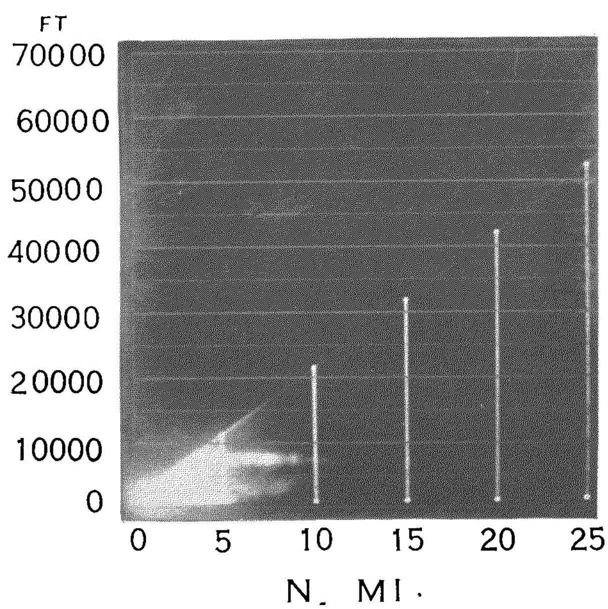

FIGURE 1.—RHI scope, 2225 EST, December 11, 1960. Settings: 25-mile range; azimuth 111°; 4-microsecond pulse length; reduced gain.

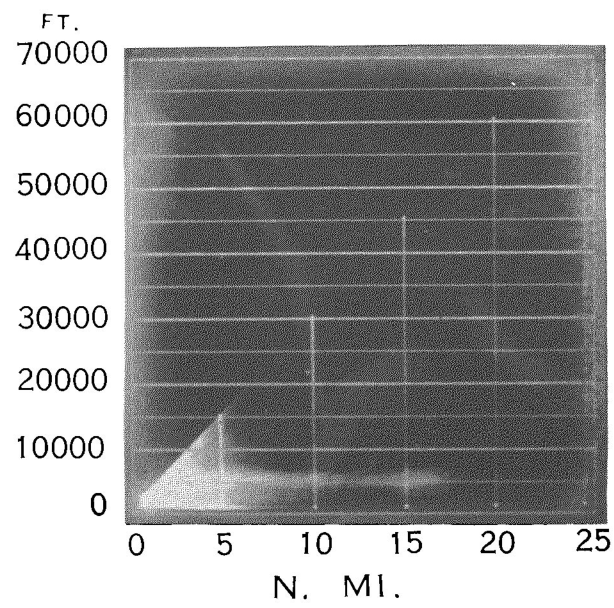

FIGURE 2.—RHI scope, 0215 EST, December 21, 1960. Settings: 25-mile range; azimuth 137°; 4-microsecond pulse length; reduced gain.

the top of the bright band approximately 500 feet below the freezing level and the center about 1,500 feet below. (Although Weather Bureau stations transmit the top of the bright band, much of the literature to date has used the center as a reference level, to eliminate vertical distortion.)

In figures 5 and 6 the temperature in the inversion layers is less than 0° C. However, it should be pointed out that this storm was associated with a coastal Low, and temperatures were often progressively warmer from west to east because of the advection of ocean air into the lower levels. This was reflected in the bright band, which was frequently higher east and south of the station, and on several occasions was detectable only to the east. This was the case with the bright band of figure 6, which shows little relation to the sounding. Both raobs were released from Sterling, Va., about 23 miles west-northwest of the airport, and computations based on the low-level winds aloft indicate that, in each case, the balloon was within a few miles of the release site at the altitude of the radar bright band.

The bright band of figure 5 was observed in all quadrants, to 15 n. mi. Assuming an average sounding just slightly warmer than that indicated, it seems reasonable to consider the top of the stable layer near 6,000 feet as approximating the freezing level, with the top of the bright band 1,000 feet, and the center 2,000 feet below this point. As we have assumed a little warmer sounding, it is possible that these height differences may have been slightly greater, since the freezing level could have been somewhat higher than 6,000 feet. Note that the sharper inversion of figure 4, promoting relatively faster melting of the frozen precipitate, produced a higher (with respect to the freezing level) bright band than that of figure 5.

AN/TPQ-11 Observations.—Figures 7, 8, and 9 are photographs of the facsimile record of the AN/TPQ-11 radar. In the recorder unit the paper is transported from left to right, therefore on the facsimile trace the earlier times are to the right. There are two height scales shown in the photographs: 15,000 feet and 30,000 feet. The horizontal lines represent 5,000-foot height intervals while the vertical lines are 5-minute time increments.

In figure 7a most of the chart shows a gradually lowering layer of precipitation aloft, approximately 15,000 feet thick. On the left side the scale has changed from 30,000 to 15,000 feet with 45 decibels of attenuation (gain reduction) inserted. The rather broad pattern remaining is the bright band, in this case a fairly thick layer. Although the base of the precipitation aloft is below 5,000 feet, the reported ceiling was 14,000 feet estimated, and later, 12,000 feet measured. Again, as with the WSR-57, this illustrates the tendency of radar to portray precipitation rather than cloud droplets. This detection preference has been commented on by Atlas and Kessler [3] in a recent evaluation of the AN/TPQ-11. Figures 8 and 9 are examples of narrower, somewhat better defined bright bands, although both are weaker (less gain reduction), and often discontinuous. In figure 9 the bright band is steadily

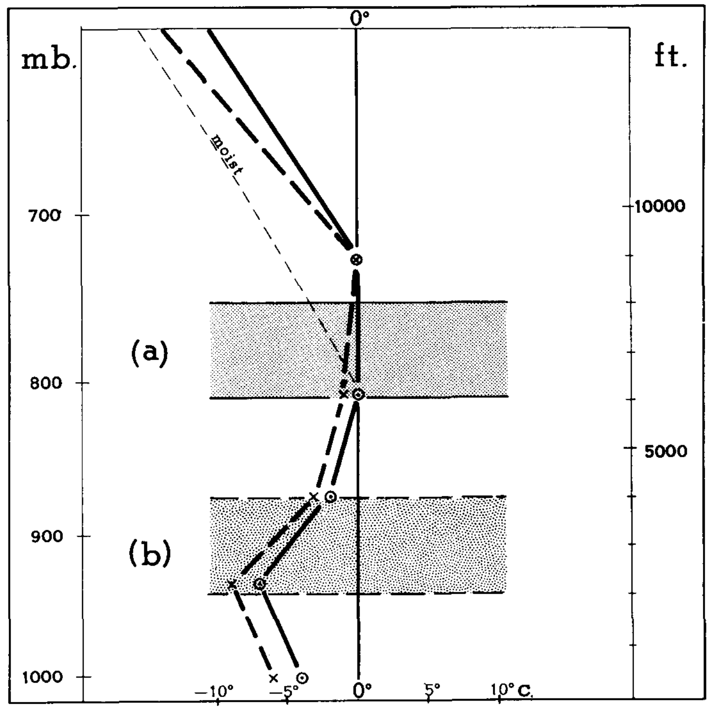

FIGURE 3.—WSR-57 bright band and secondary layer of 2225 EST, December 11, 1960 superimposed (stippled) upon the 1800 EST (release time) upper-air sounding of the same date.

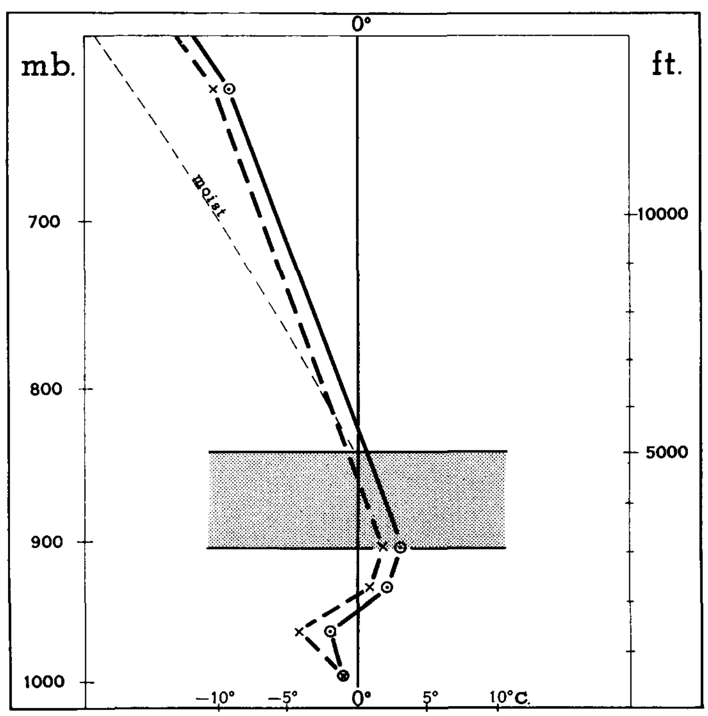

FIGURE 4.—WSR-57 bright band of 0600 EST, December 21, 1960 superimposed (stippled) upon the upper-air sounding of the same time (release time) and date.

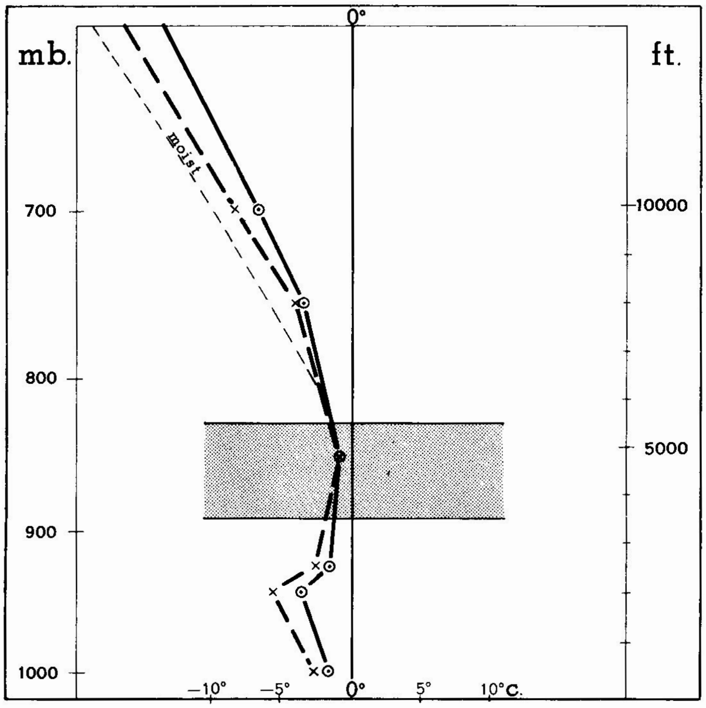

FIGURE 5.—WSR-57 bright band of 0600 EST, February 8, 1961 superimposed (stippled) upon the upper-air sounding of the same time (release time) and date.

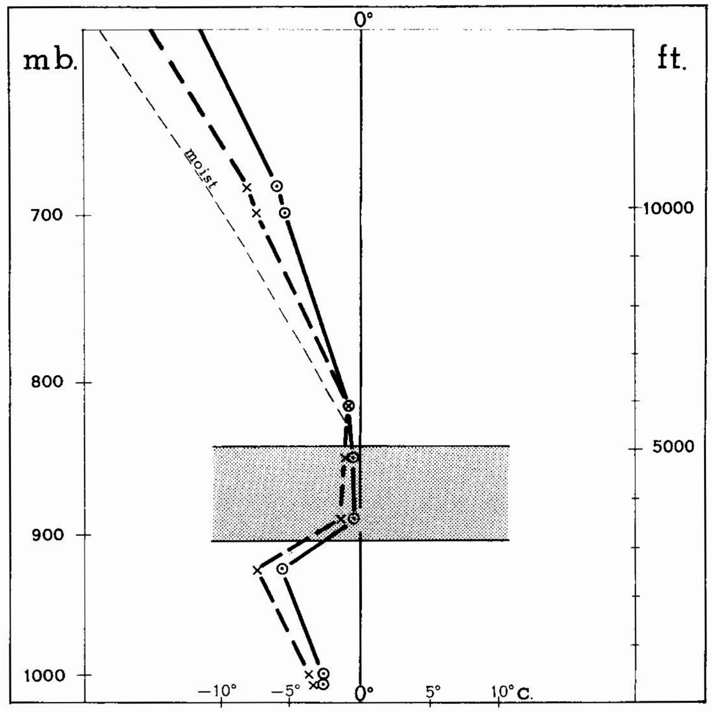

FIGURE 6.—WSR-57 bright band of 1800 EST, February 8, 1961 superimposed (stippled) upon the upper-air sounding of the same time (release time) and date.

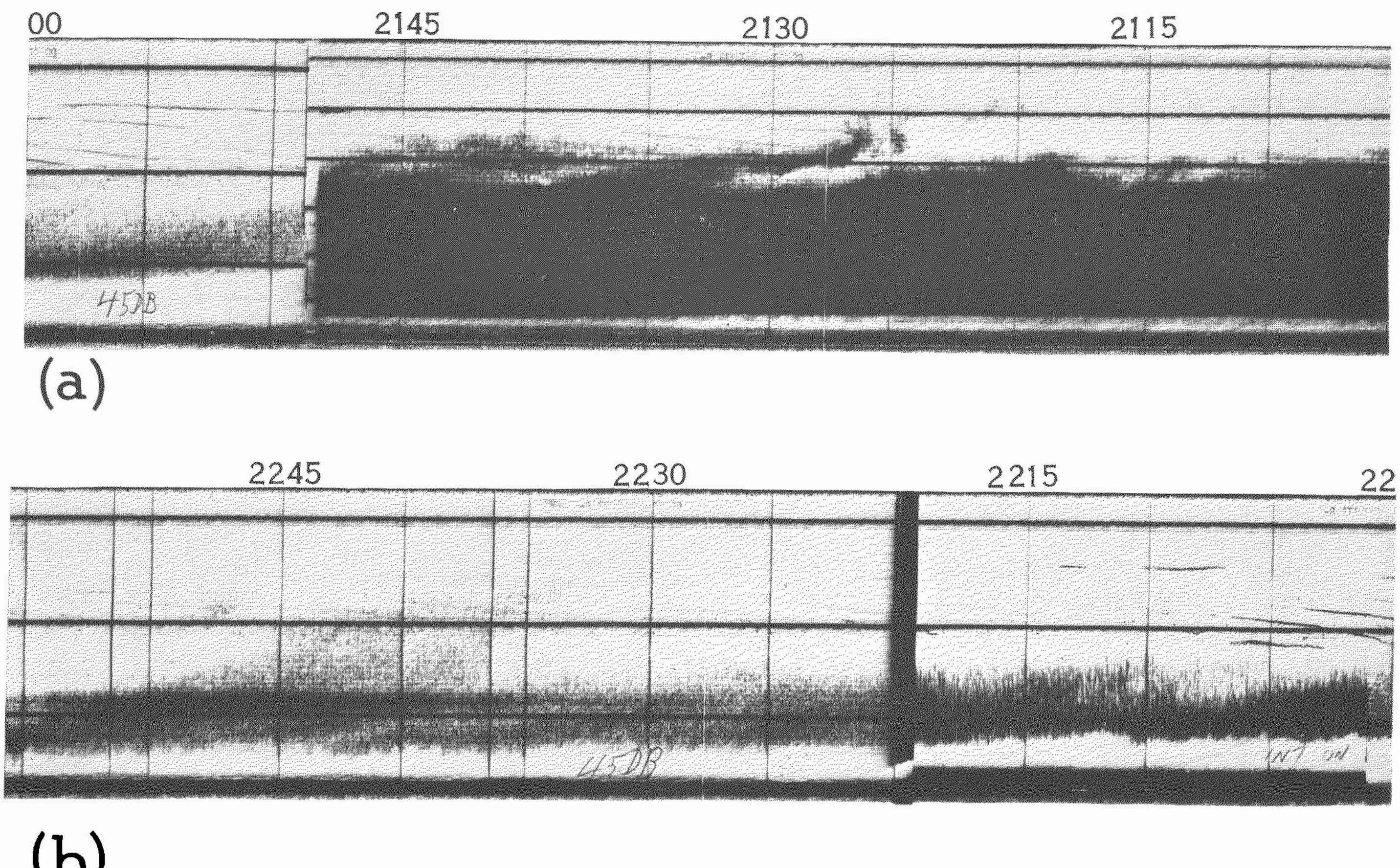

FIGURE 7.—AN/TPQ-11 facsimile trace for 2105 to 2255 EST, February 7, 1961. The horizontal lines represent 5,000-foot height intervals.

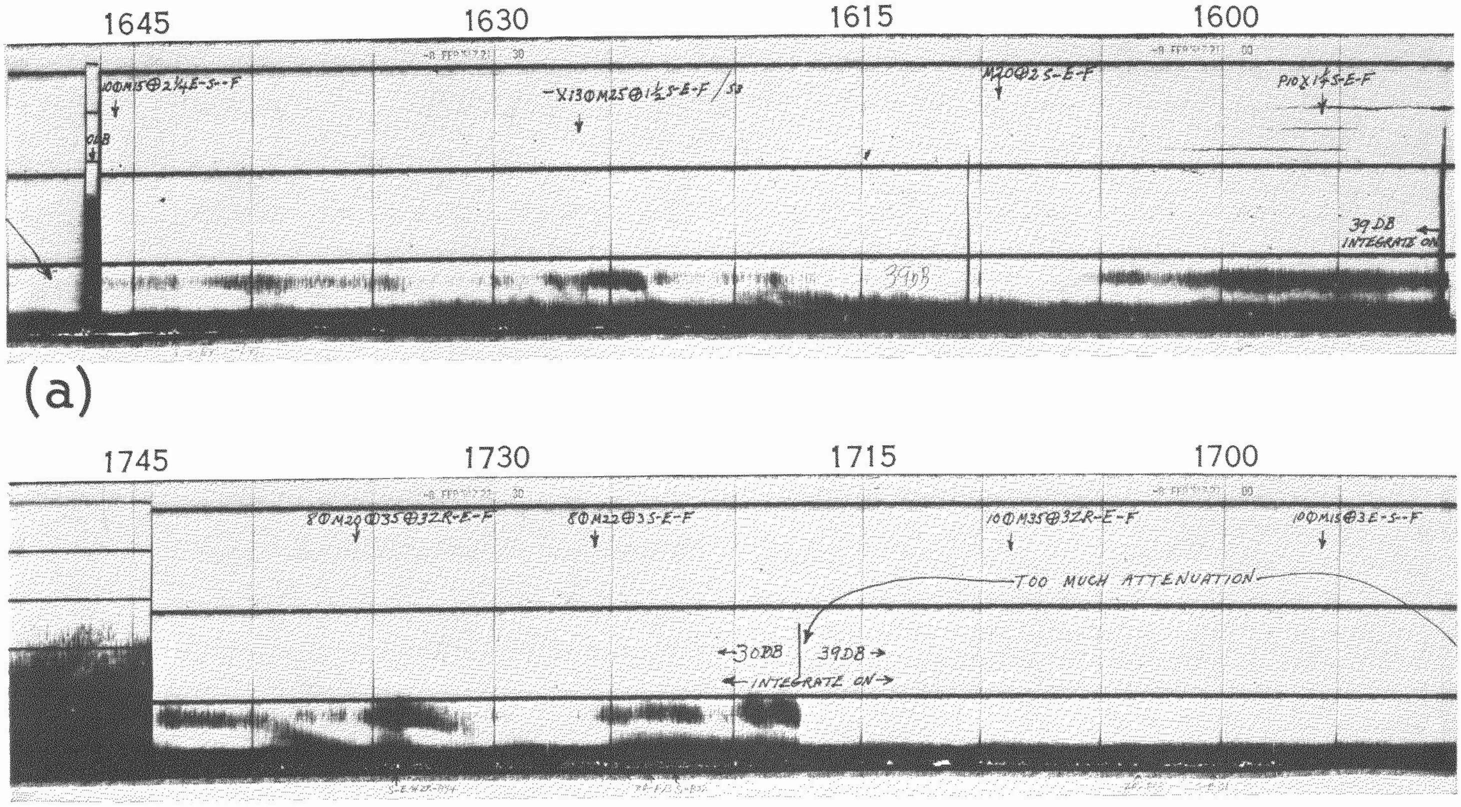

FIGURE 8.—AN/TPQ-11 facsimile trace for 1550 to 1750 EST, February 8, 1961. The horizontal lines represent 5,000-foot height intervals.

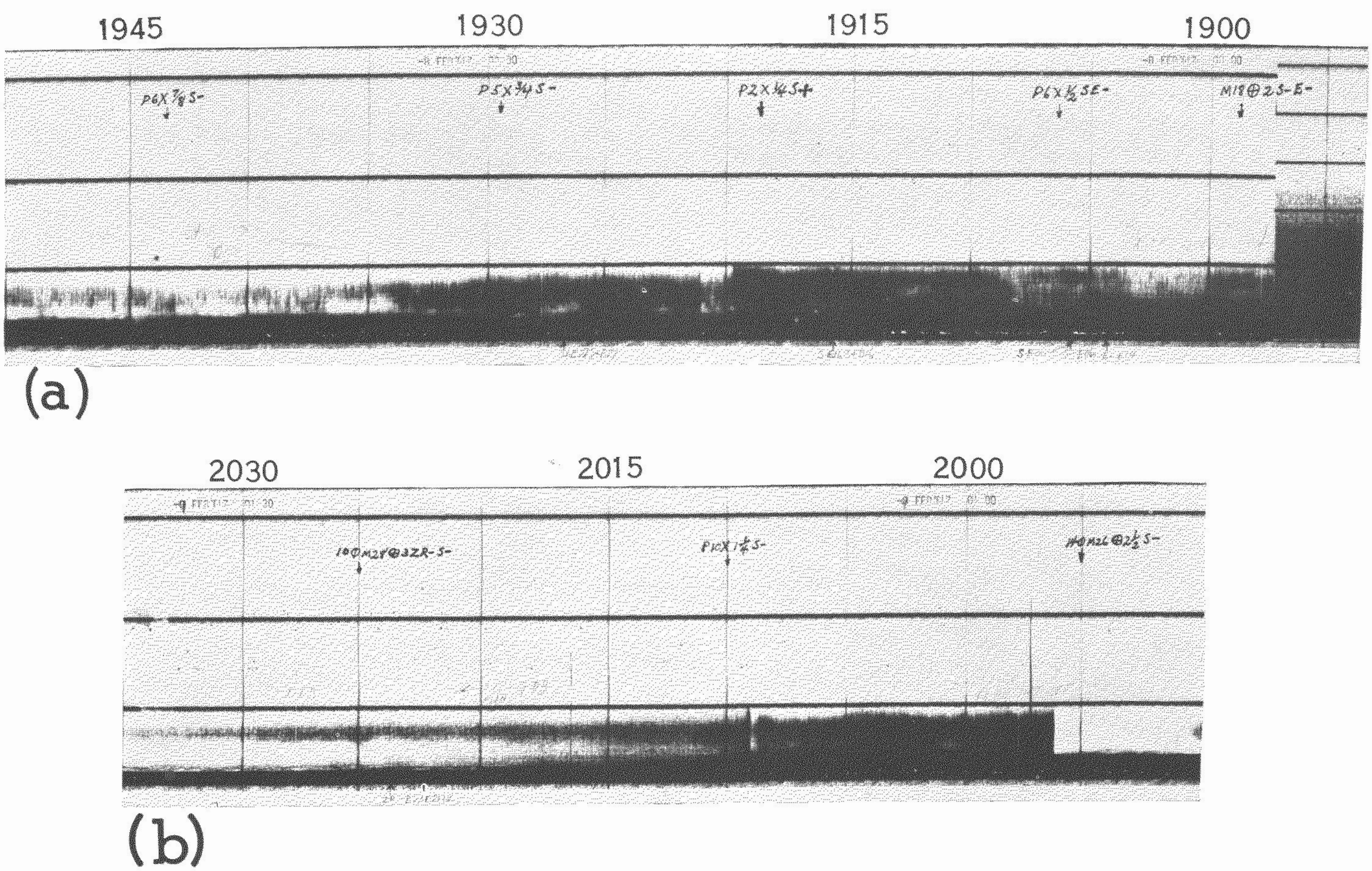

FIGURE 9.—AN/TPQ-11 facsimile trace for 1845 to 2035 EST, February 8, 1961. The horizontal lines represent 5,000-foot height intervals.

TABLE 2.—*Comparison between WSR-57 and AN/TPQ-11 radar observations*

Date	Time (EST)	WSR-57 observations		AN/TPQ-11 trace	
		Top (10² ft.)	Base	Top (10² ft.)	Base
2/7/61	2100	70	x		
	2149			80	50
	2255			60	25
2/8/61	0300	60	40		
	1700	40	x		
	1718			50	30
	1744			50	30
	1800	55	x		
	1900	50	x	50	30
	2000			45	25
	2035			40	35
	2100	50	x		

decreasing in intensity, almost disappearing at the left edge of figure 9b.

As shown in table 2, there appears to be fair agreement between the two radar systems. Normally, the AN/TPQ-11 radar, with a vertically-pointing beam subject only to a small pulse-width error, as compared to the beam-width error of the WSR-57, should be more accurate in this type of measurement, although fairly heavy precipitation will cause this short wavelength radar to attenuate badly, losing much of its detection capability.

Comparing the AN/TPQ-11 trace with the 1800 EST raob of February 8 (fig. 6), we find the top of the bright band at 1744 EST approximating the top of the stable layer at about 5,000 feet, 500 feet below the top of the WSR-57 bright band. Even assuming that this stable layer, at some point, did reach the 0° C. isotherm, the lapse rate would hardly have supported rapid melting, and any bright band formed should be found some distance below the top of this layer. Here too, then, as with the WSR-57 observation, the bright band is too high to fit the sounding, and implies a warmer sounding over the station.

3. SUMMARY

During three snowstorms of the 1960-61 season, radar bright bands were detected at Washington National Airport when surface temperatures were at, or below, freezing. Examination of the upper-air soundings made during these storms confirms the existence of inversions aloft in the vicinity of the radar bright bands. A comparison of the heights recorded for the WSR-57 bright bands with those of the AN/TPQ-11 presentation indicates a reasonable degree of correlation between the two systems.

ACKNOWLEDGMENTS

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3. D. Atlas and E. Kessler, III, "Category 1 Radar Cloud Detecting Set AN/TPQ-11," Aerophysics Laboratory, Air Force Cambridge Research Laboratories, Bedford, Mass., Mar. 1961 (See Appendix II).